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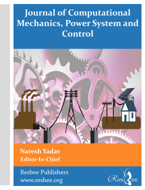

High-Performance MPPT based on Fast Convergence for PV System-Experimental Validation

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Abstract: The connection between a photovoltaic generator (GPV) and a DC load is always a subject of study. The impedance matching between a Photovoltaic (PV) Generator and a Direct current (DC) load is a technological problem that essentially consists in transferring the maximum power from the PV generator to the load. The work presented in this paper concerns the optimization of the photovoltaic conversion chain using advanced algorithms. The study of photovoltaic system components showed that the main element is the conversion chain that must be optimized to extract the maximum power from the GPV generator. Thus, in order to find the maximum power point, the insertion of a matching stage between the GPV and the load is necessary. This step has been realized in our case using a DC / DC boost converter programmed with many algorithms namely Perturbation and observation (P&O), and Intelligent Control (IC), which are traditional algorithms, and the advanced method, which is a fast convergence approach, which is the method proposed in this work.

Keywords: DC/DC Converter, IC, MPPT algorithm, Modelling, Load emulation, Photovoltaic generator, P&O, Photovoltaic power systems, Power system control.

1. Introduction

In recent years, the growing need for energy and the pollution caused by the use of fossil fuels is pushing the public to use renewable energy [1]. In this context, photovoltaic energy is one of the important renewable energy sources that present a solution to our energy production problems. Moreover, this energy seems the most promising, non-polluting, and inexhaustible. In addition to being silent, it integrates perfectly into buildings (facades, roofs...), and because it does not include moving mechanical parts, it does not require special maintenance and remains reliable for a long time, which is why it has become a reference in space applications and in isolated sites. It is becoming a safe bet for small and medium energy consumption applications, especially since solar panels have become cheaper and more efficient [2].

The consumption rate of photovoltaic (PV) cells is not only associated with the internal characteristics of PV cells [9]. However, it is also affected by environmental factors, like load, irradiance, and temperature. In a complex environment, to make PV cells in the best working state, the MPPT approach that has been used in PV systems can be roughly categorized into 4 types, such as optimized MPPT approach, conventional MPPT approach, hybrid MPPT approach, and, intelligent MPPPT approach [10].

The hybrid MPPT approach is an integration of the intelligent approach, which is, the conventional MPPT model is initially utilized to calculate the MPP region, and subsequently intelligent optimization is utilized to identify the precise MPP. The hybrid approach in existing studies can integrate the benefits of the techniques; however, it employs high-level mathematical computation and has poor applicability [10].

This work aims to study the different types of tracking mechanisms to charge a battery from the point of view of efficiency and complexity, through simulations under various atmospheric conditions

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so that the test is real and practical to detect their disadvantages and advantages over each other and then try to conclude their respective qualities. For the purpose of the test, we have made a low-cost Maximum Power Point Tracking (MPPT) charge controller designed to work with a solar panel of a hundred watts. This system will be used to improve the performance of the photovoltaic conversion chain for applications such as battery charging and DC load supply.

2. System Model

To show the efficiency and performance of the method proposed in this work, the PV system shown in figure 1 is the system used in the various stages of the study of this system.

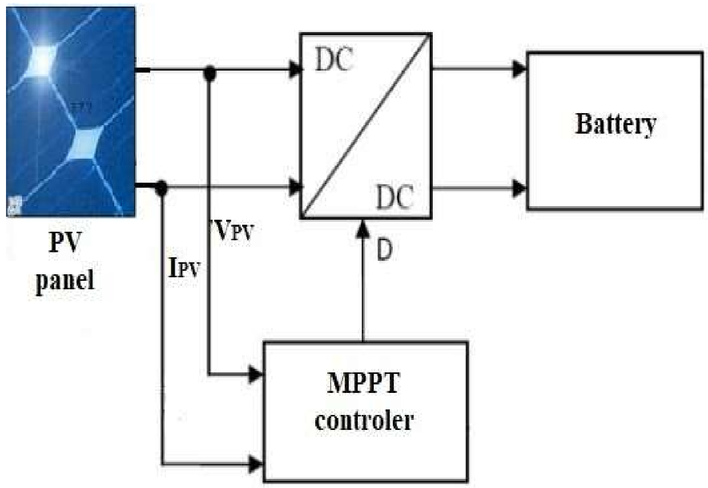


Fig.1. *Synoptic scheme of the conversion chain*

This PV system as shown in this figure contains the PV generator, which is an assembly in series and/or in parallel with the PV cells, the adapter between the source and the load which is a boost converter controlled by a control circuit based on different MPPT algorithms and a DC load. The DC load is a battery, to be charged exploiting the maximum of power delivered by the PV generator.

3. MPPT Algorithms

There are several operating principles of MPPT controls more or less efficient based on the properties of the GPV. A synthesis of the main existing MPP search modes allows us to choose the right algorithm that will meet the requirements such as speed and accuracy of the system.

3.1 P&O Algorithm

P&O is one of the most commonly used techniques to implement MPPT control in a PV system. The principle of P&O is based on the disturbance of the system by increasing or decreasing a voltage Vpv, where the duty cycle of the DC-DC converter is directly affected, and then observing the effect on the output power of the panel [3].In summary, if following a voltage disturbance, the PV power increases, and the disturbance direction is maintained. Otherwise, it is reversed to resume convergence to the new MPP.

3.2 Incremental Conductance Algorithm

The incremental conductance method is based on the fact that the slope of the power characteristic curve produced by the photovoltaic generator is zero at the MPP, positive at the left, and negative at the right as shown in figure 2 [4]:

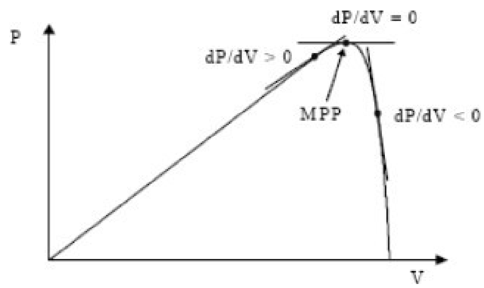


Fig.2. *Sign of dP/dV at different positions of the power characteristic curve.*

The maximum power point MPP is given by the equation (1):

$$\frac{6P}{6V} = \frac{6(\mathrm{VI})}{6V} = 1 + V\,\frac{6I}{6v} \cong l + V\,\frac{\Delta \mathrm{I}}{\Delta v} = 0 \tag{1}$$

From this equation, we conclude the following operating points:

$\frac{\Delta \mathrm{I}}{\Delta v} - - \frac{\mathrm{I}}{v}$ *at MPP*

$\frac{\Delta \mathrm{I}}{\Delta v} - - \frac{\mathrm{I}}{\nabla}$ The left-hand side of M*PP*

$\frac{\Delta \mathrm{I}}{\Delta v}, \frac{\mathrm{I}}{v}$ The right-hand side of M*PP*

In this algorithm, the point of maximum power can therefore be pursued by comparing the instantaneous conductance I/V with the conductance increment ΔI/ΔV to achieve the maximum power point [5].

3.3 Fast Convergence Approach

Fig. 3 presents the characteristic of a PV module for different irradiations where the maximum power points are marked. A virtual load line is also sketched, which correspondsto the following equation [6]:

$$\mathrm{Vpv\text{-}rIpv\text{-}Vref=0} \tag{2}$$

The operation of the MPPT converter along this line is realized by the simple control loop shown in the flowchart (figure 4), where equation (2) is realized by a current sensor withan appropriate gain "r". Since the MPP locations are not on a straight line, the value of Vref istuned, so that the virtual load line moves to different locations, while maintaining its tilt, which is defined by the gain r. In this way, the PV generator is operated at the actual MPP at any given irradiation [7].

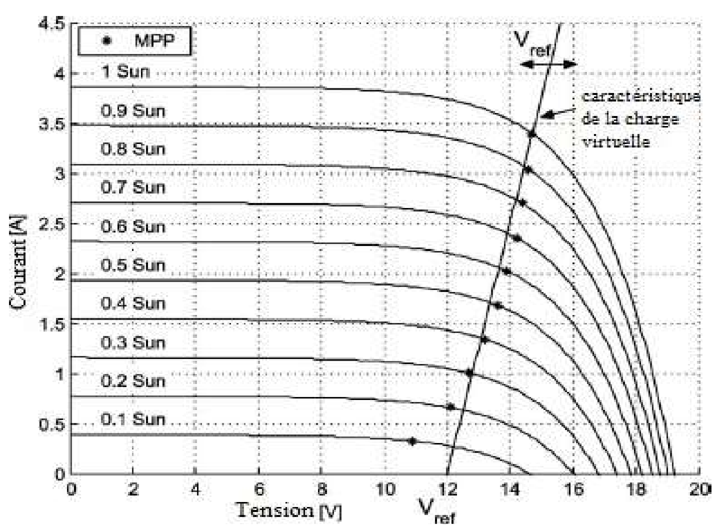


Fig.3. *PV Panel Characteristics and the Emulated Load Line*

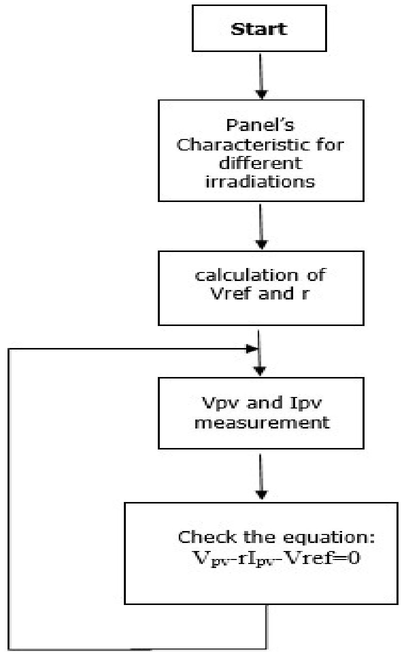


Fig.4. *Flow Chart of the Fast Convergence Approach*

4. Experimental Validation

To validate experimentally the results obtained by the theoretical study we use the synopticschema of the PV system given in figure 1. This system consists of a photovoltaic module, a power circuit composed of a MOSFET-based boost converter and a battery and a control circuit, a current sensor, and a voltage sensor as presented in figure 5.

4.1 Real Characteristics of PV Module used in Experimental Validation

More and more, the efficiency of photovoltaic panels is decreasing due to several factors such as misuse, aging of cells, and fatigue of other components. For these reasons, the real characteristics of the SGM-FL panel are studied by a direct connection of the PV panel with a rheostat. These characteristics are taken under irradiation 1061W/m2, a temperature of 31°C, and an inclination of 30° towards the South. These characteristics are given in figure 6.

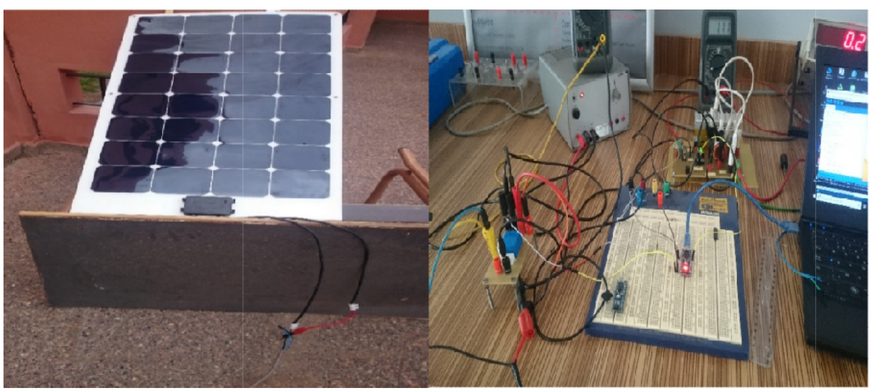


Fig.5. *Materials used in the Experimental Part*

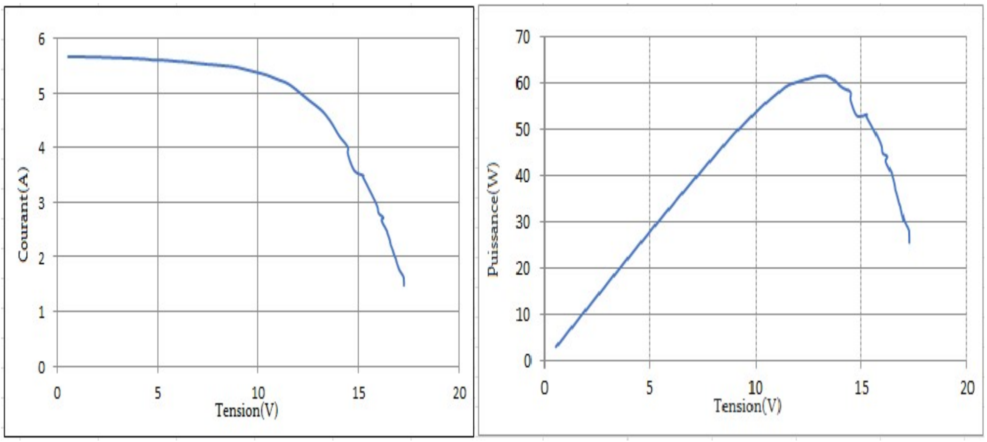


Fig.6. *Real characteristic IV and PV of GPV SGM-FL*

Therefore, the actual characteristics of the SGM - FL module are given in Table 1.

Table 1: Real electrical characteristics of the sgm - fl panel

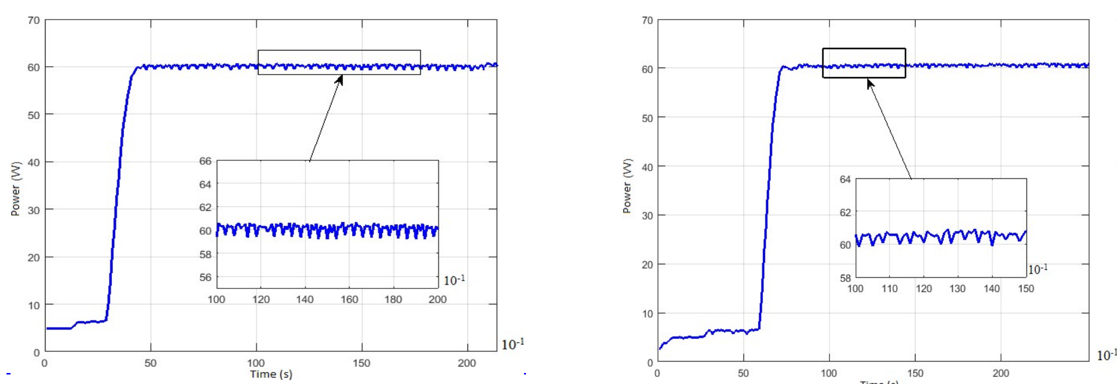
Pmax	**62.33 W**
Voc	17.5 V
Vmp	13.29 V
Isc	5.64 A
Imp	4.69 A

4.2 Experimental Results

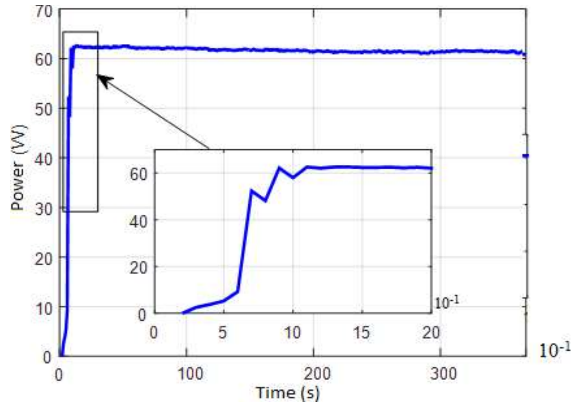
Under the irradiation of 1063W/m2 and temperature 33°C as shown in figure 7, we carried out several experimental readings, to study the behavior of the PV panel voltage Vpv, the PV panel current Ipv, and the power of the PV panel P.

We studied the experimental behavior of the current of the GPV (IPV), of its voltage (VPV), and consequently its instantaneous power (PPV) on precise readings obtained with the software of acquisition PLX-DAQ on short intervals of time.

The results of the implementation of MPPT algorithms are given in the following figures:



(a) (b)



(c)

Fig.7. *Practical results: (a) P&O algorithm, (b) IC algorithm,(c) Fast convergence approach*

The results in Figure 7 show the efficiency of the different algorithms in tracking the maximum power point. For the P&O, there are oscillations around PPM due to incremental step size. If the step width is large, the MPPT algorithm will respond quickly to sudden changes in operating conditions, but losses will be increased in stable or slowly changing conditions. On the other hand, if the step width is very small, the losses in steady or slowly changing conditions will be reduced, but the system will not be able to keep up with rapid changes in temperature or insolation.

From the results obtained, it is clear that the "InCond" algorithm is more complex than the P&O one. This technique presents small oscillations and a small error because it is difficult to fulfill the condition dP/dv=0.

From the experimental results obtained, the fast convergence approach shows it is efficient in the MPP track, especially at the transient level since it quickly converges to the maximum power of the PV generator after a few milliseconds. This approach leads to good performances since it has a faster response time, despite the existence of small oscillations in the steady state due to the PI controller parameters used in this approach.

5. Conclusion

Due to the conventional MPPT of PV, the array was easy to fail in a complex environment, and the conventional intelligent optimization approaches have some disadvantages, like low convergence precision, slow convergence speed, and poor stability. In this paper, we have shown the feasibility of a medium-power Photovoltaic (PV) system with a digital MPPT control using a control board. Based on the results of the simulations of the different algorithms, we experimented with the system several times on cloudy days where the illuminance underwent sudden variations. The results obtained allowed us to conclude that the implemented algorithms, present a good agreement between the experiment and the simulation. Moreover, no discrepancies were observed during the operation of the photovoltaic energy conversion chain.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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